STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

CALIFORNIA'S THIN BONDED PCC OVERLAY

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83-04

A0-58

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO FHWA/CA/TL-83/04	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO
4. TITLE AND SUBTITLE CALIFORNIA'S THIN BONDED PCC OVERLAY		5. REPORT DATE June 1983
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) B. F. Neal		8. PERFORMING ORGANIZATION REPORT NO. 19303-633352
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Transportation Laboratory California Department of Transportation Sacramento, California 95819		10. WORK UNIT NO
		11. CONTRACT OR GRANT NO. F81TL03
12. SPONSORING AGENCY NAME AND ADDRESS California Department of Transportation Sacramento, California 95807		13. TYPE OF REPORT & PERIOD COVERED Interim
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This project was performed in cooperation with the U.S. Department of Transportation, Federal Highway Administation.

16. ABSTRACT

Details of a thin bonded PCC overlay of a 17 year old PCC pavement are presented. The location was on I-80 near Truckee at 6500-7000 ft elevation. Due to the extent of bond failure, the project is considered to have "failed", and was overlaid with AC. Results of the failure investigation to date are also given.

17. KEY WORDS Abrasive blasting, bonding, concrete pavements, failure, grout, overlay course, overlay thickness.	18. DISTRIBUTION STATEMENT No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified		

DS-TL-1242 (Rev.6/76)

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mmm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2) acres	.09290 .4047	square metres (m^2) hectares (ha)
Volume	gallons (gal)	3.785	litres (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) kips (1000 lbs)	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (ft-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi $\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ (MPa $\sqrt{m}$)
	pounds per square inch square root inch (psi $\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ (KPa $\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)

ACKNOWLEDGEMENTS

The contributions of the numerous District Headquarters and Laboratory personnel involved in this study are gratefully acknowledged.

TABLE OF CONTENTS

INTRODUCTION

Approximately 70 miles of Interstate 80 in California are in an area of numerous freeze-thaw cycles where tire chains are frequently required in winter months. The highway crosses the Sierra Nevada mountains reaching a summit elevation of about 7,200 feet. The final sections of this 4-lane (plus truck - climbing lanes on grades) portland cement concrete (PCC) facility were constructed in 1964. The combined effect of traffic and environment has resulted in extensive surface degradation.

Although typical defects such as joint faulting, cracking and joint spalling associated with aging PCC pavement are displayed, the major problem of this facility is the loss of wearing surface. To the motorist, the noise caused by his tires rolling over the exposed aggregate surface is objectionable. The loss of the pavement section is becoming significant, initially through the loss of the surface texture, then the surface mortar, to the current condition of losing occasional 1 1/2" aggregate particles.

Restoring a satisfactory riding surface to the pavement and halting the surface degradation have been matters of concern for several years. Since most of the roadway is considered structurally adequate, complete reconstruction or placement of thick, unbonded PCC overlays are not deemed desirable strategies. Asphalt Concrete (AC) overlays have been used at lower elevations quite successfully, but have been only marginally satisfactory in mountain areas. A variety of alternative restoration measures have been proposed for evaluation on this portion of I-80.

Those selected for evaluation included:

(1) A thin (3 in. nominal thickness) bonded PCC overlay using high quality concrete with a low water-cement ratio.

(2) Very thin (3/8 in. thickness) "exotic" concrete overlays using materials relatively new to highway construction.

(3) An asphalt concrete overlay employing new binder/ modifiers and design concepts.

The first project has been completed and is the subject of this report.

CONCLUSIONS

1. The thin bonded overlay on I-80 did not perform satisfactorily. Excessive loss of bond just prior to winter necessitated an AC overlay.

2. Bond loss is believed due to shear failure induced by thermal stresses. Possibly these stresses are developed to higher levels in California than in other areas where thin bonded overlays have been constructed, namely, Iowa, Louisiana and New York. This is presumably due to greater daily temperature fluctuations.

3. Increasing the surface area of base concrete, such as is created by a cold planer, can provide improved resistance to shear stress and a resulting improvement in bonding properties.

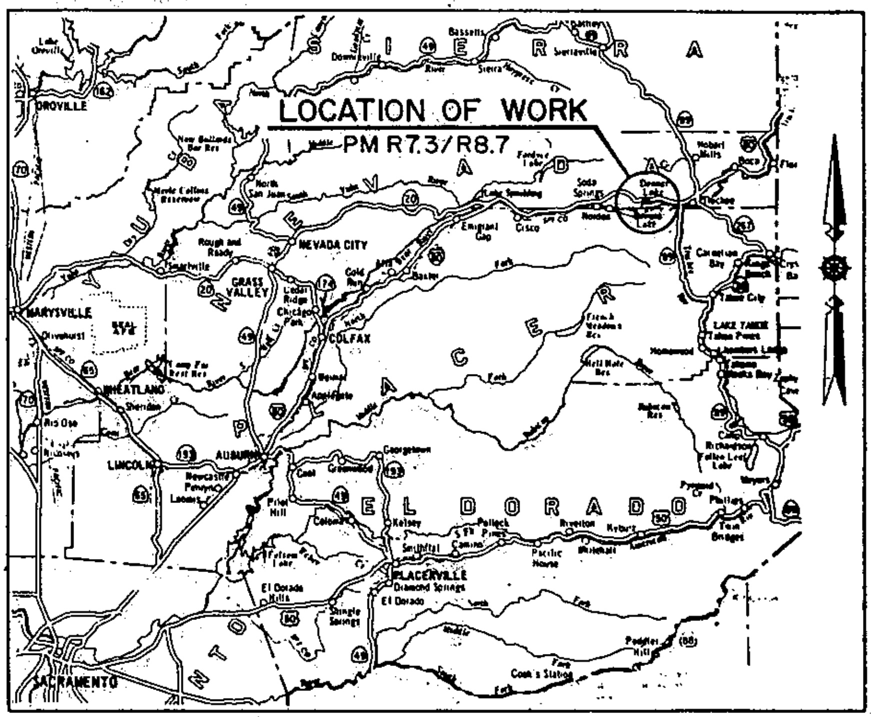
4. Bonded overlays using cement grout as the bonding agent are not considered viable for the California environment. A more positive bonding material, such as epoxy, is considered necessary.

PCC OVERLAY PROJECT

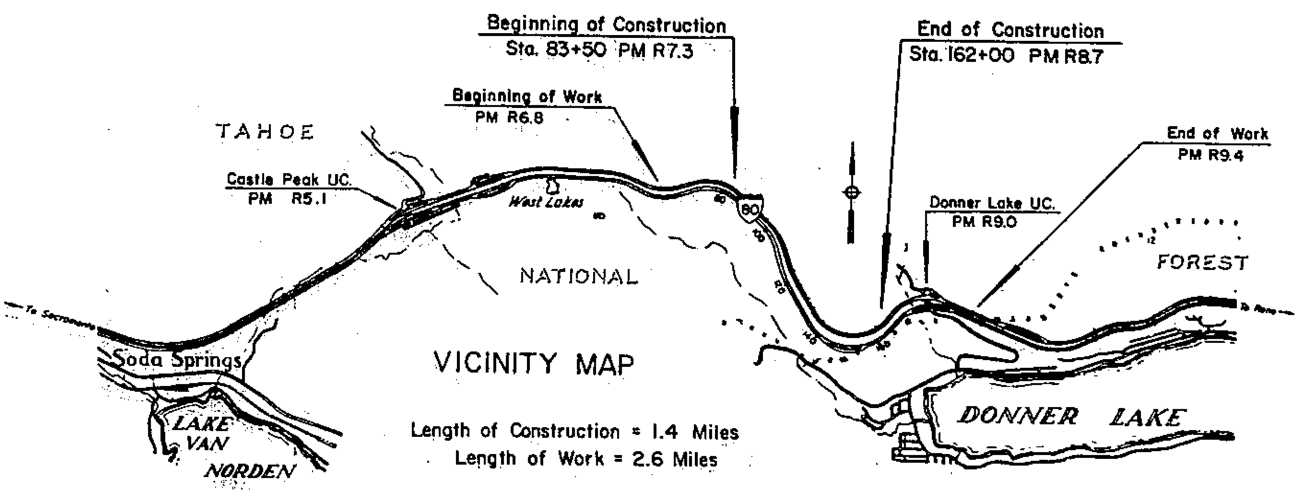
Site Selection

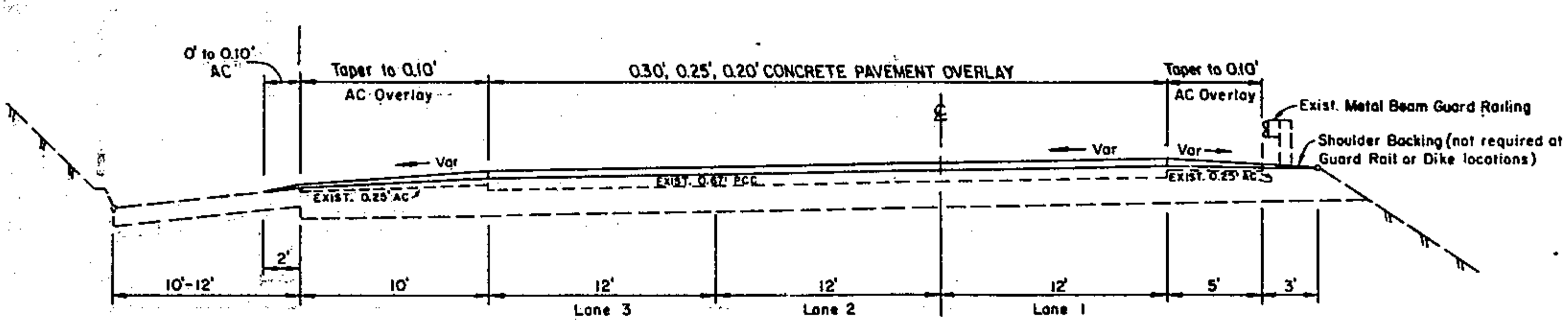
Major concerns in the selection of a site for the experimental construction included: (1) the project should be of sufficient length to allow the progress and quality of construction procedures to stabilize; (2) the site should be such that traffic control could be maintained at a reasonable cost; and (3) inconvenience to the motoring public should be kept to a minimum. A 1.5 mile section of 3-lane roadway was selected (Fig. 1). The location is in the westbound roadway in an area of sidehill construction in steep terrain and is on a sustained 5+% grade approaching the Donner summit (7200 ft). The typical cross section in this area has a 10-ft wide zone outside the conventional shoulder width for snow storage.

Since the pavement was considered structurally adequate, no overlay design procedure was used to establish overlay thickness. Based on experience, a basic thickness of 0.25 ft was chosen. For experimental purposes, sections of 0.20 and 0.30 ft thickness were also included. These thicknesses are considered sufficient to restore riding quality, arrest surface attrition, and, incidentally, increase structural strength.



LOCATION MAP





Sta. 83 + 50 - 162 + 00

WESTBOUND LANES

TYPICAL CROSS SECTION

Scale 1" = 5'

FIG. I

Other variables selected for evaluation included aggregate size, treatment of cracks, joint sealing, and reinforcement used over cracks and joints. The variables and reinforcement details are shown by Appendix A along with portions of the special provisions.

Prior to construction, a condition survey was made of the existing pavement. Aerial photographs were found to be extremely useful in mapping cracks. The reinforcement details sheet in Appendix A shows the cracking pattern on a portion of the project which is typical of the entire 1.5 mile section. Lane 3, the truck lane, had the most cracking and surface attrition (100% of the textured surface). Lane 2 had lost about 50-70% of the original textured surface and lane 1, about 10-20%.

Riding quality, as indicated by Road Meter measurements, was reasonably good. Deflection measurements (made with a Benkleman Beam and an 18 kip axle load) at joints were consistently low (0-0.005 in. in most cases).

The base pavement was constructed in 1964 with 0.67 ft concrete over 0.33 ft cement treated base. Joints were constructed by sawing at a skew and staggered spacing standard at the time - a counterclockwise skew of 2 ft in 12, and repeat spacing intervals of 13, 19, 18 and 12 ft. While some joints had been sealed with preformed neoprene material, most had a two-component joint sealant. Over the years rubber asphalt had been added to the joints as the original sealants deteriorated. Traffic data indicated that, through 1980, this roadway had accumulated 5,700,000 equivalent 18 kip axle loads or more than double the design loading.

The contract was awarded to the low bidder, Teichert Construction Co. of Sacramento, in May of 1981. Work on the project began in early June.

The first stage of the work involved reconstruction of the existing outer shoulder and snow storage area to provide a 12 ft wide traffic lane (Lane #4) of asphalt concrete and a new 8 ft paved shoulder. The initial overlay placement was on lanes 1 and 2, monolithically, with lane 3 closed during the working day and lane 4 carrying uninterrupted traffic. At the close of each day and during the period of strength gain lane 3 was opened to traffic.

As the overlay on lane 3 was placed the median shoulder and lanes 1 and 2 were striped to carry 2 lanes of traffic through the entire construction period.

Surface Preparation

Surface preparation consisted of cleaning by sandblasting with hand-held nozzles (Figs. 2 and 3). Although this was a rather slow operation, the results were considered to be satisfactory. Initially, the pavement was thoroughly cleaned, and then again blasted lightly just ahead of the paver. Rubberized asphalt that had been used to reseal joints was removed by cold-milling. On each end of the project, cold-milling was used to remove a tapered section of concrete ranging from 0 to 2 in. over a 60 ft length to provide transition into the overlay section. Spalled areas of significant size were patched with fast-setting magnesium phosphate concrete.

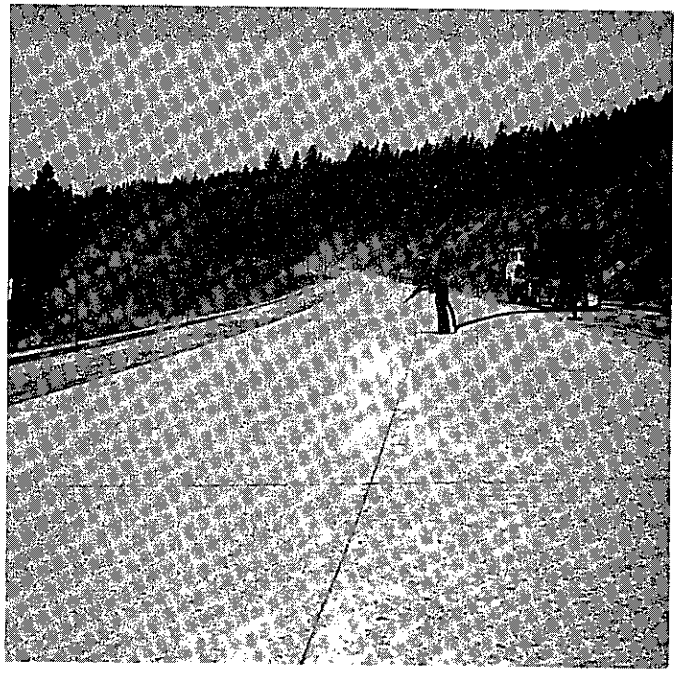


Fig. 2

Fig. 3

Bonding Grout

A neat cement grout was specified for bonding and was supplied by a commercial pressure grouting specialist using trailer-mounted mixing and pumping equipment (Fig. 4). The selection of a spraying wand to apply the grout was based on tests conducted before the project was started (Figs. 5 and 6). The thickness of application required adjustment by trial and error. A thin coating dried before the overlay concrete could be spread over it. Average coverage for the entire project was approximately 70 sq yd per sack of cement, varying from 55 to 100 sq yd per sack. Coverage was heavier on lanes 1 and 2 at 63 sq yd per sack compared to 83 sq yd per sack on lane 3.

Paving Lanes 1 & 2

Concrete for the pavement was furnished by the Contractor's commercial plant in the city of Truckee, California. The mix design called for 50% 1 in. maximum size aggregate and 50% sand with 595 lb cement per cu yd. An air entraining agent to provide 5 to 8% air and a water-reducing admixture were specified.

Paving began on June 25. Initially a problem was encountered due to a loss in slump between plant and street which resulted in completely unworkable concrete and the consequent rejection of several loads. Since the 7-cubic yard batches were hauled in end-dump trucks, the concrete could not be salvaged. The reason for this loss was believed to be the use of highly absorptive aggregate (about 3.5%) which was not fully saturated before mixing. Slump was increased to provide workable concrete delivered on the street.

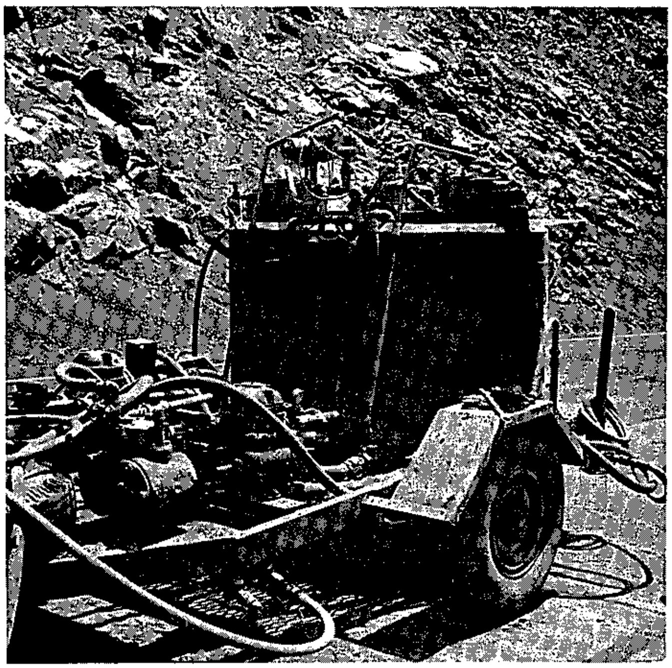


Fig. 4

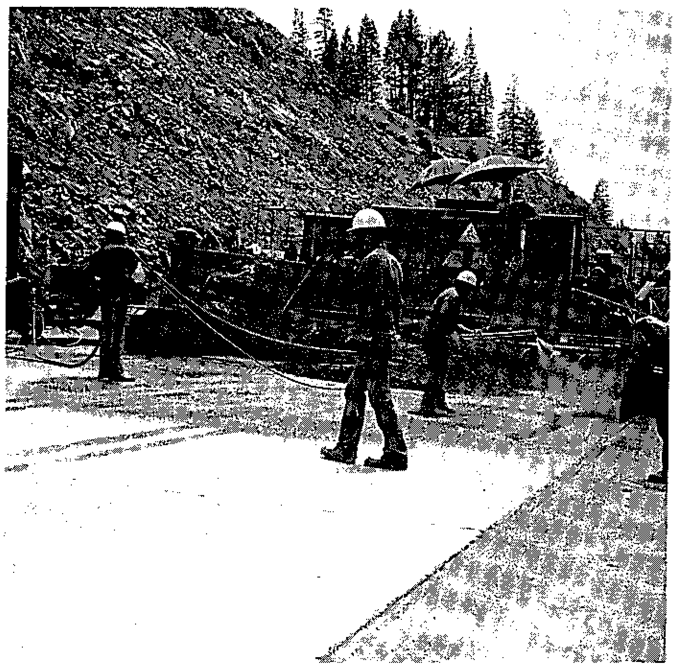


Fig. 5

Fig. 6

Although the Contractor was experienced in slipform paving, several adjustments were required to develop a smooth paving operation. The thin overlay sections required concrete placement procedures which differed from those for normal construction. Excess concrete in front of the paver created strike off problems which resulted, at times, in loss of paver traction. This condition was aggravated by the stiff concrete used for the overlay (Fig. 7) and 5% upgrade with up to 8% cross slope.

The pipe float normally used to finish the pavement surface (Fig. 8) caused surface tearing and was not employed after the first day. Final finish was accomplished by hand floating (Fig. 9) and occasional use of a bull float. Following a burlap drag, the surface was textured by metal tines forming longitudinal grooves (Fig. 10). A resin-based curing compound was then applied to the surface (Fig. 11).

Because of the rapid drying conditions resulting from relatively high temperatures (80° to 86°F), low humidity (10 to 15%) and wind (12 to 18 mph), fogging of the pavement was specified. Fogging was to begin approximately 2 hours after paving began and continue until 4:30 p.m. The Contractor attempted to keep the pavement wet by spraying across the two lanes with a water truck. At times, lane 1 was not appreciably wetted due to strong winds blowing counter to the spray (Fig. 12).

Transverse joints were specified to be directly over existing joints. They were formed by saw-cutting full depth of the overlay along a previously referenced line (Fig. 13). Sawing usually began around 5:30 p.m. and was

Fig. 7

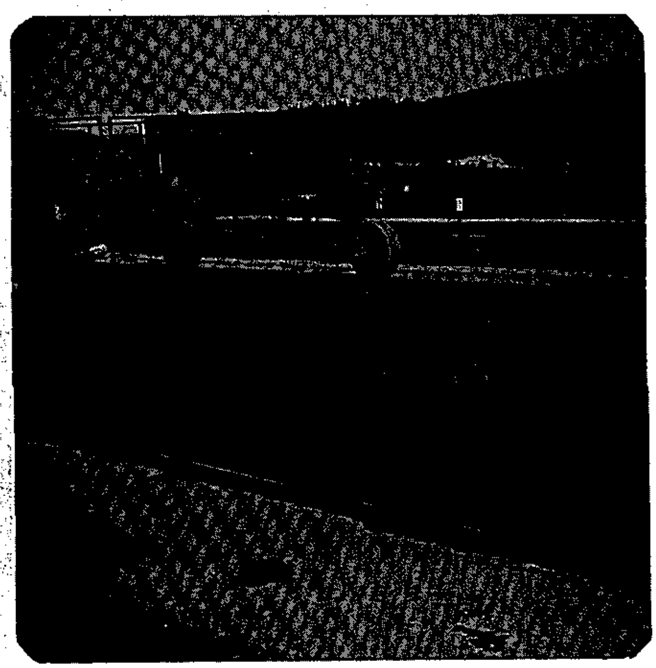


Fig. 8

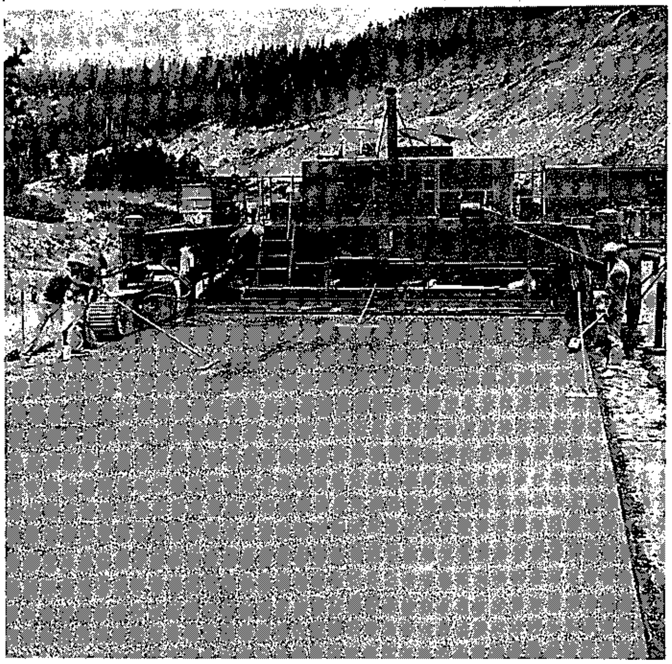


Fig. 9

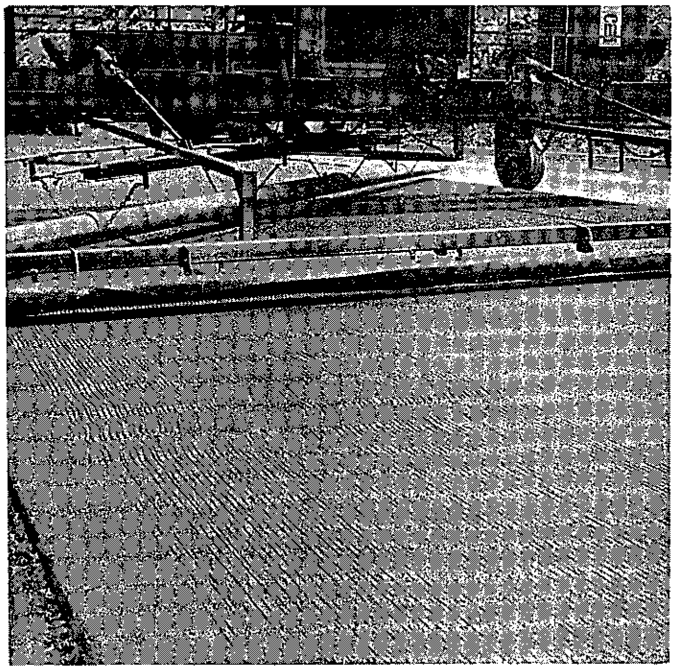


Fig. 10

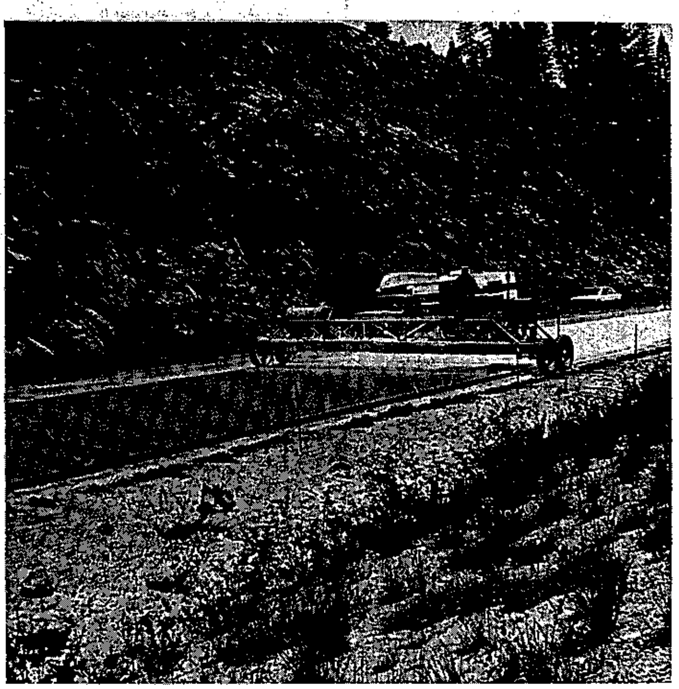


Fig. 11

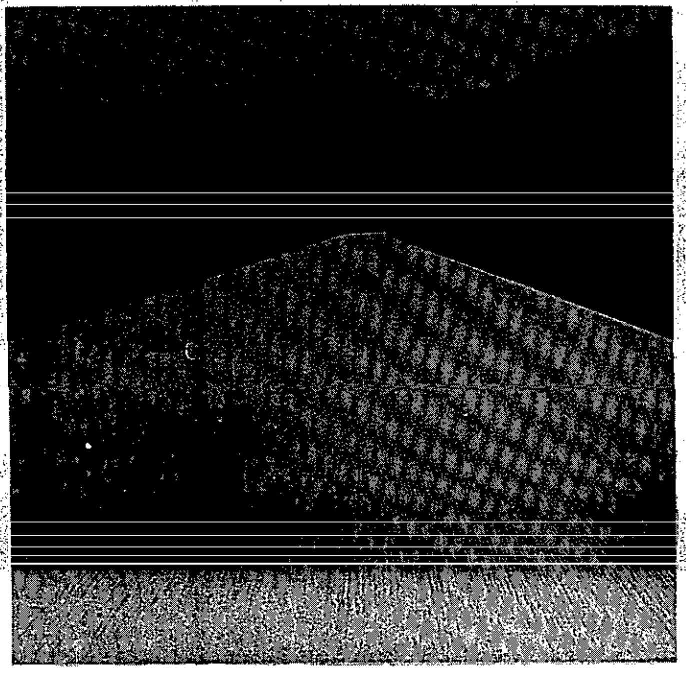


Fig. 12

Fig. 13

completed between 10:00 and 12:00 p.m. A longitudinal weakened plane joint was not specified because matching the existing joint was not considered feasible.

Where reinforcement over cracks or joints was specified, mats were preformed and fastened to the pavement shortly ahead of the paver. Initially, wire was used to tie the mats to nails driven into the concrete. This proved to be inadequate as the mats would often be displaced by the paver (Fig. 14) and cause a delay in the paving operation while the problem was corrected. Later, steel straps were placed over the reinforcing bars and nailed to the pavement to prevent mat displacement (Figs. 15 and 16).

Paving of lanes 1 and 2 was completed in 5 days as planned. Production rates varied from 800 ft the first day to 2550 ft on the fourth day.

During the next two weeks grinding of rough areas was completed, joints were prepared and sealed, the 5-ft median shoulder paved, and temporary traffic markings were placed.

Bond Tests

The shear tests performed in the laboratory on 4 in. cores from the overlay (Fig. 17) indicated adequate bond at age 2 to 3 weeks with values ranging from 350 to 550 psi. Compressive strength tests on the separated cores indicated values between 5,000 and 6,000 psi for the new concrete (age 2 to 3 weeks) and 6,000 to 8,000 psi for the existing.

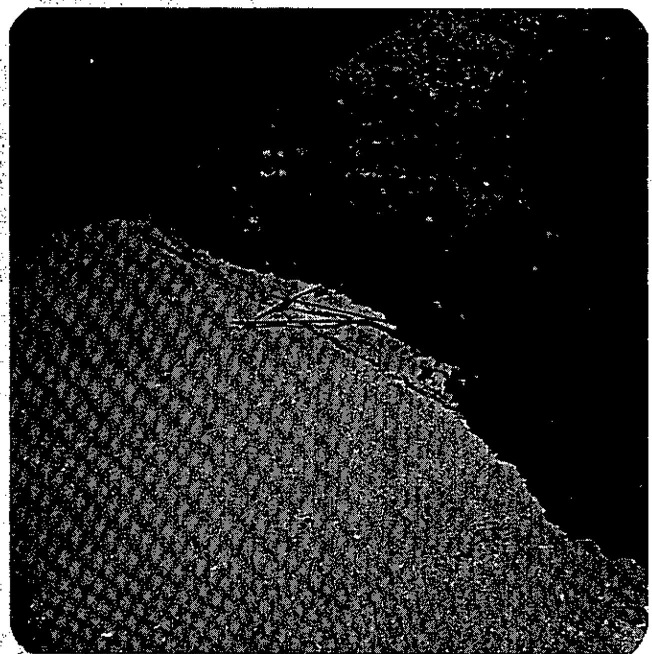


Fig. 14

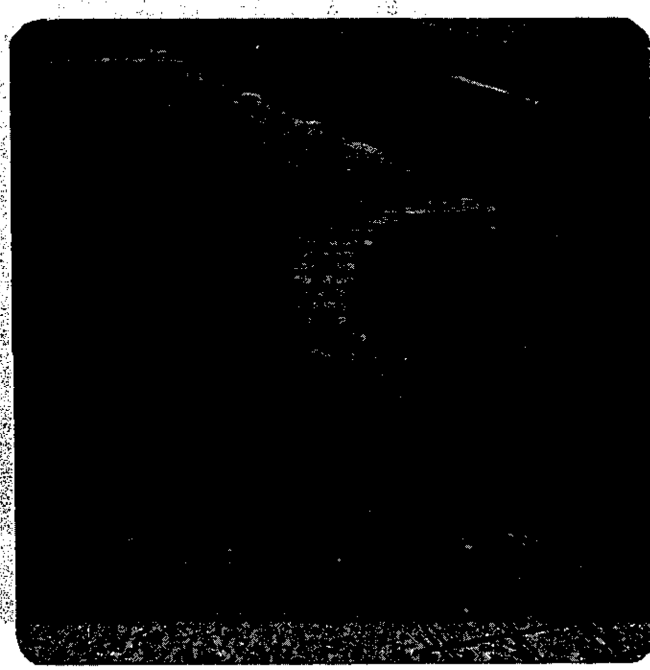


Fig. 15

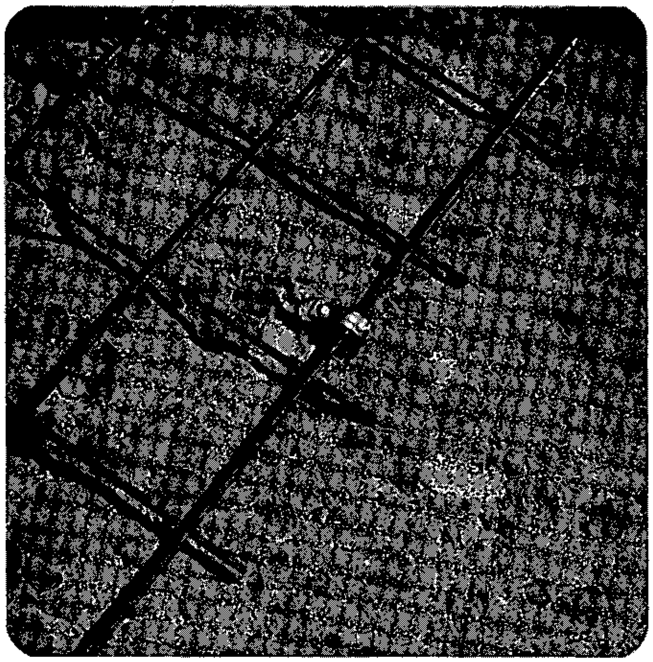


Fig. 16

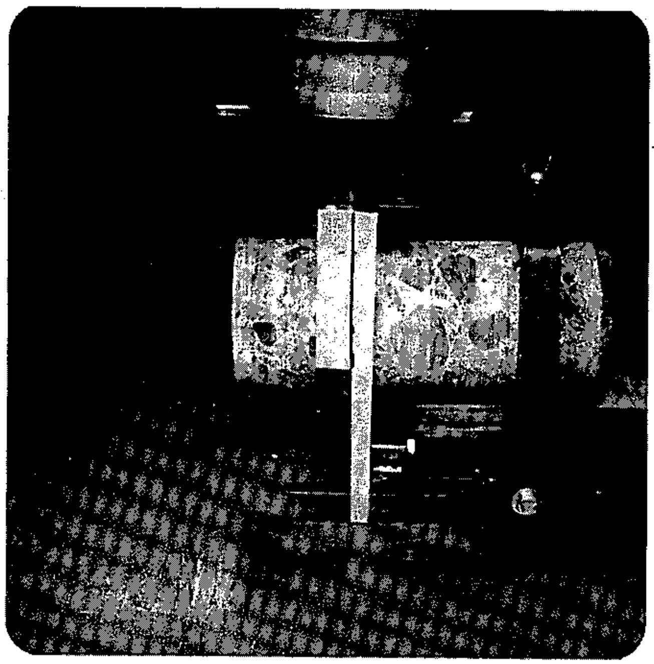


Fig. 17

Cracking

On close examination, it was found that most of the overlay slabs had transverse cracks at pavement edges. While the cracks were very tight and not easily detected, they were numerous, in some instances, as close as 1 ft apart. The cracks generally could only be traced for about 1 or 2 ft from the pavement edge and were usually less than 1 in. deep.

After a thorough study of existing conditions at time of paving, several conclusions were made regarding the cracking:

1. Cracking was apparently due to volume change of the overlay concrete at an early age. Contributing factors were:

a. High evaporation rate. Based on a chart in the Portland Cement Association "Design and Control of Concrete Mixtures", the evaporation rate was probably as high as 0.3 lb per sq ft per hr. Cracking may occur if the rate exceeds 0.1 lb per sq ft per hr.

b. Differential fresh concrete and base concrete temperatures.

c. High temperature differential from day to night (up to 50°F in ambient temperature plus an additional 40°F in concrete surface temperature).

d. High shrinkage concrete. Concrete made with aggregates from the project has about double the shrinkage value of that made with aggregates considered about average in shrinkage properties for California sources. The water-reducing agent used for the project (meeting ASTM C494 Type A) caused a further significant increase in shrinkage.

e. The amount and duration of the fogging was inadequate for the adverse drying conditions.

2. Cracking was not associated with the time of day or ambient temperature at which concrete was placed.

3. Cracking was not associated with wind direction.

4. Cracking was not associated with the direction of superelevation or whether pavement was in cut or fill.

Based on the above conclusions as to the cause of cracking, it was decided to make two changes when paving the third lane. The coarse aggregate stockpile was to be wetted in an effort to provide saturated aggregate for batching. Also, fogging was to be extended until 7:00 p.m. Since only a single lane was involved, no problems were anticipated in the application of a spray to the entire surface.

<u>Paving Lane 3</u>

On July 17, traffic was switched to lanes 1 and 2. Surface preparation of lane 3 was then started with completion on July 22. Paving began on July 28 and was completed in 3 consecutive days. No problems were encountered.

Bonding Problems

On August 6, cores were obtained in lane 3 for bond tests. With some work underway on lane 3, a portion of lane 2 was also closed which permitted the recovery of cores in that lane. A core taken adjacent to a crack and near a joint was found to be unbonded. A second core (10 ft away) was taken and later tested at 400 psi shear bond. Sounding the area with a hammer revealed the unbonded area to be rather extensive in that slab. Moving to an adjacent slab, other unbonded areas were found. Random soundings for approximately 1/2 mile continued to reveal unbonded or delaminated areas. Consequently an investigation of the extent of delamination over the entire project was initiated.

From August 11 thru 14, a survey party sounded lanes 2 and 3 (Figs. 18, 19, 20). A survey of lane 1 was completed August 21. To check on the progression of delamination, a second survey of lanes 1 and 2 was made on August 24 and 25, and of lane 3 on August 27 and 28. A third survey of short sections of lane 1 was made September 17, and of lane 3 on September 22.

Paint was used to outline the delaminated areas, with different colors used for successive surveys. Following the second survey, new photographs were taken of the project showing the paint marks. Planimeter measurements were used to measure the amount of delamination.

The following is a chronological summary of events for each lane:

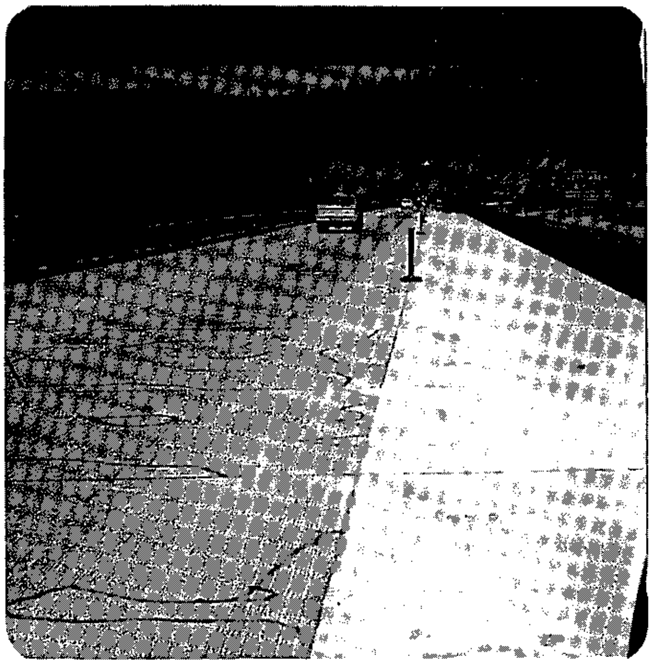


Fig. 18

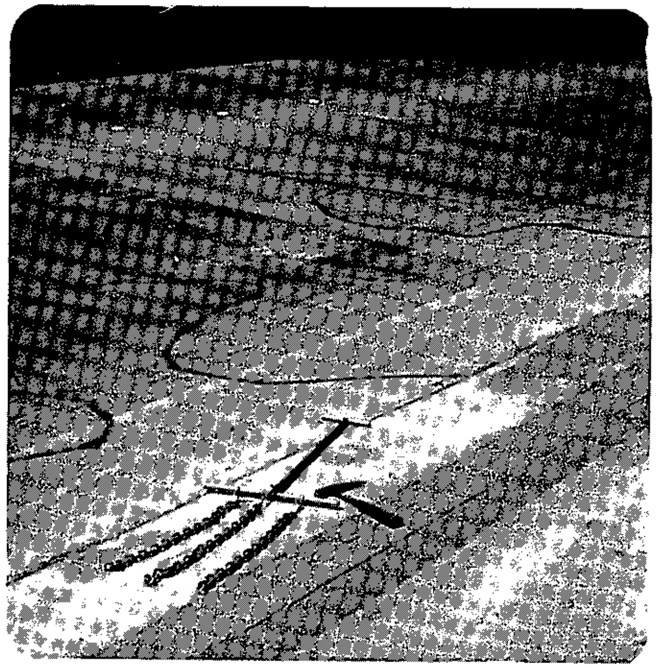


Fig. 19

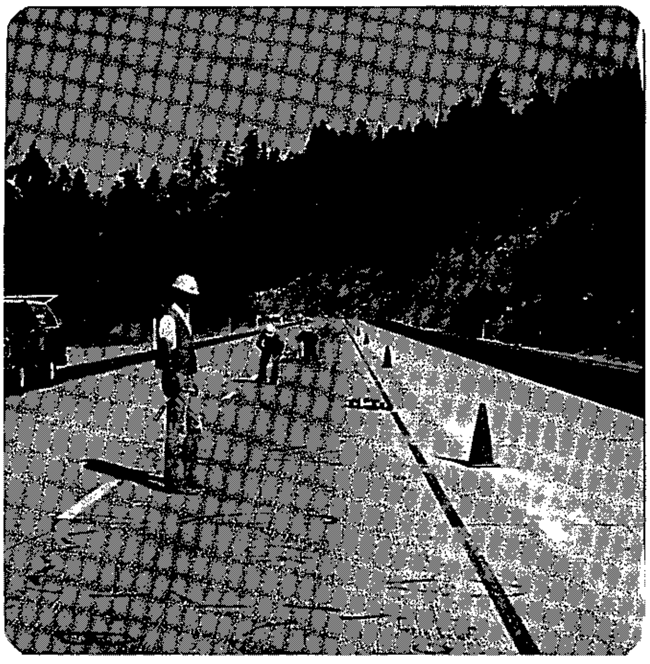


Fig. 20

Lane 1

6/25 - 7/1/81	Pavement placed
7/17	Opened to traffic
8/19 - 8/21	1st survey: 28% of total lane area showed delamination. Based on short individual sections, it ranged from as little as 5% to as much as 88%.
8/24 - 8/25	2nd survey: Delamination increased.
9/17	3rd survey of short sections: No consistent pattern of progression. Some areas showed no increase while one 200 ft length had an increase from 31% to 38%

Lane 2

6/25 - 7/1/81	Pavement placed
7/17	Opened to traffic: Although closed much of the time during the day due to construction of lane 3.
8/10 - 8/14	1st survey: About 5% of entire area delaminated with range from 1-15%.
8/24 - 8/25	2nd survey: Delamination increased from 5% to 9% of total area with some individual areas up to 28%.

Lane 3

7/28 - 7/30	Pavement placed
8/10 - 8/14	1st survey: Less than 1% of total area delaminated. One 200 ft section had 9%. No transverse cracking found.
8/18	Opened to traffic
8/27 - 8/28	2nd survey: An increase to 3% of area. The bad delaminated section increased from 9% to 43%. Transverse cracking was insignificant.
9/22	3rd survey of short sections: Most had negligible increase but the badly delaminated section increased from 43% to 55%. Extrapolating the results of the short sections, delamination of the entire area of lane 3 should not exceed 5%.

Although the area of delamination in lanes 2 and 3 was relatively low, lane 1, with about a third of the area already delaminated, was of major concern. With winter approaching, an immediate decision on possible mitigation was necessary. It was feared that large pieces of the overlay could be dislodged by ingress of water and subsequent freezing. If this occurred during stormy conditions, repairs would be difficult. The test section could constitute a driving hazard and potential hazards to the public and to equipment during snowplowing operations also had to be considered.

A decision was made to attempt epoxy injection in lane 1 to determine whether this means of repair was viable. Three different companies specializing in the injection procedure contracted to try their process for one or more days. All began work on August 25, each in a different area. At the end of the day none of the three had finished injecting two complete pavement slabs. It was obvious that this procedure would not be satisfactory. Subsequently, the decision was made to overlay the entire project with asphalt concrete (see Appendix B for details).

Bond Failure Investigation

Since discovery of a debonding problem, efforts have been made to determine the reasons for failure and hopefully, means to prevent it. Other agencies indicated no such experience with bond loss and could only suggest certain areas to investigate.

There was some concern over thickness of grout layer and the drying of grout before covering with concrete. While no attempt was made to measure the actual thickness, it appeared adequate to observers, including those who had observed thin bonded overlay construction in Iowa. When the grout surface was observed to be drying, another coating was sprayed on prior to paving. Attempts were made to obtain further information on grout behavior and condition by examining surfaces of cores after separation. Although a layer of grout could be detected on the base pavement portion, no conclusions could be drawn as to thickness or condition at time of overlay.

It was suggested that the pavement should have had a wet surface before applying the grout. This is not consistent with the results of past experimentation and the experience of the Iowa Department of Transportation which indicates that better bond is obtained when the overlay concrete is placed on a dry surface. Possibly, when a pavement is hot, a fog spray slightly ahead of paving might provide a beneficial cooling effect on the base pavement.

As previously stated, the pavement surface was considered adequately prepared for the overlay by the sandblasting operation. However, it was not a deep blast providing aggregate relief or even exposing much aggregate in lane 1. Lanes 2 and 3 had large amounts of aggregate exposed from surface attrition. There is a definite correlation between the amount of delamination in each lane and the amount of aggregate exposed, i.e., less delamination with more aggregate exposed. Whether this is due entirely to a greater surface area or in part to better bond to aggregate than to mortar is not clear. Even though the bond was much improved in lane 3, the amount of delamination (3-5%) is probably more than would be considered acceptable as a standard.

There has been occasional minor debonding noted on airport pavement overlays(1,2), however, no attempt was made to repair the debonded areas and some of the overlay pavements are still in use. A recent report(3) of a thin bonded PCC overlay project in Louisiana mentions delamination at exterior slab corners. The problem was not believed to be serious but will be monitored.

A thin low slump dense concrete bridge deck overlay placed on I-80 in 1980 was examined after the highway problem was discovered. Soundings with chains and hammers indicated small areas of delamination which were verified by coring. Voids at the bottom of some of the cores (apparently due to insufficient vibration) reduced the area in contact with the base concrete and probably contributed to the loss of bond. No such condition could be found on any of the highway overlay cores.

Laboratory Tests

To gain more insight into mechanics of failure, a laboratory testing program was initiated. A supply of materials used on the project was obtained from the Contractor's plant. In late September, a slab 1 ft x 8 ft x 3 in. thick was cast on existing concrete using project materials, but with the grout coat brushed on rather than sprayed. The base concrete was quite smooth and was not sandblasted. Strain gages (4 inches in length) were installed both vertically and horizontally at each end of the concrete overlay (Fig. 21). Thermocouples were installed to measure temperature at the top and bottom of the overlay concrete. All gages were connected to recorders and set to print hourly readings. Fig. 22 shows the completed slab.

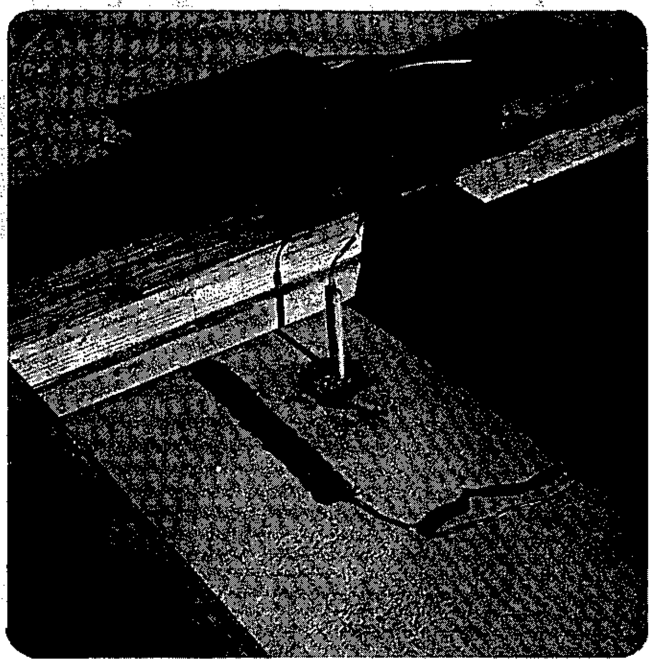


Fig. 21

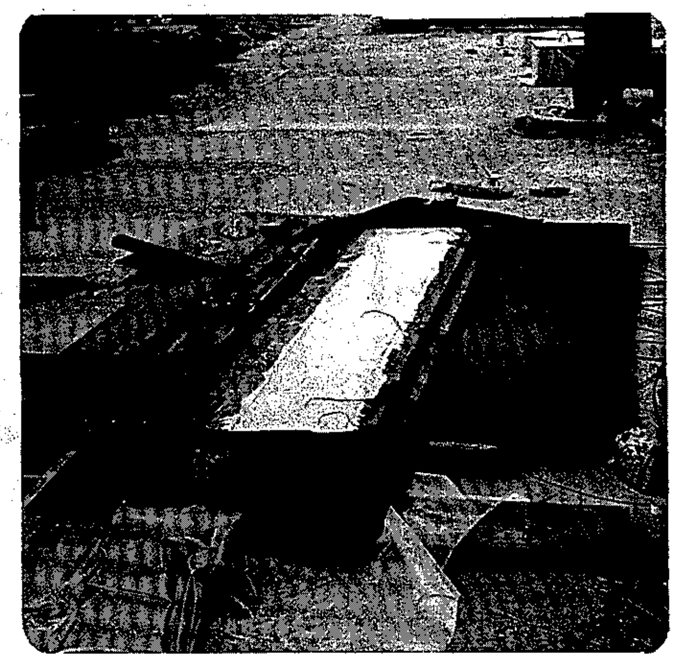


Fig. 22

Each week day morning, the ends of the slab were sounded for delamination. On the 7th day, a Monday, both ends were found to be delaminated. The area was defined as well as it could be determined. The length was about 10 inches on one end and 12 inches on the other. In another week it had progressed an additional foot. The unbonded areas were quite irregular, being considerably longer on the edges than in the center (Figs. 23 and 24).

Although most of the strain gage readings showed very little change, the vertical gages indicated considerable strain. The actual values recorded, however, were those at the interface of the two slabs and not over the entire 4-inch gage length as usual. Therefore, these values are only useful to show relative strain and time of maximum strain. The following table shows the maximum and minimum strain in the vertical direction. Although only readings of one gage are shown, the other gage followed precisely the same pattern.

STRAIN - MICROINCHES

Age, Days	Max		Min
0	0		0
1	300		240
2	360		250
3	500		340
4	780		600
5	1180		700
6	1280		670
7	1430	(Found Delamination)	610
8	1840		900
9	1850		910
10	1950		920

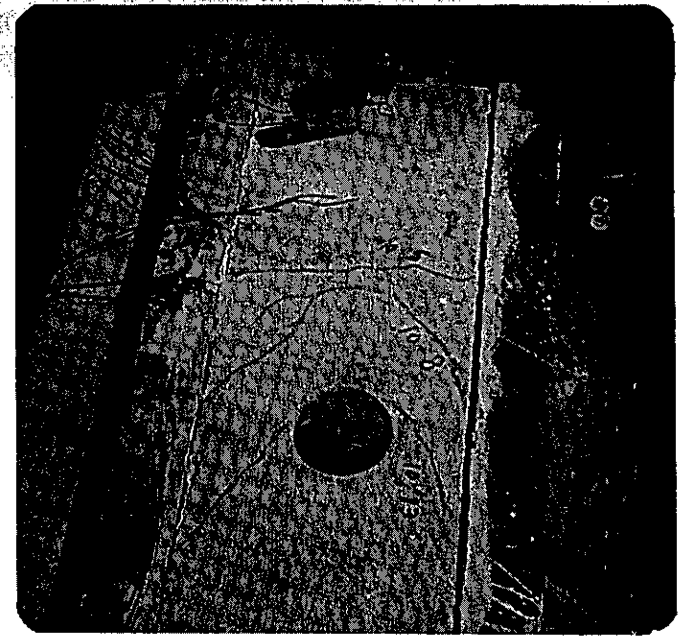


Fig. 23

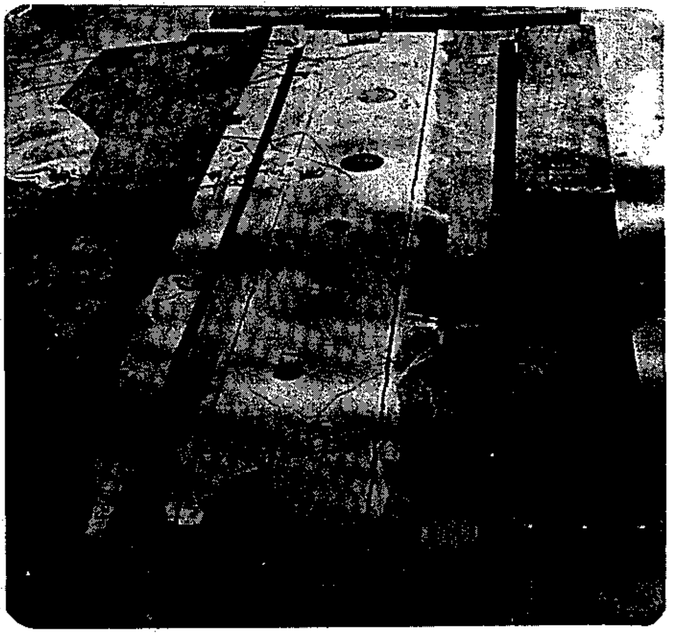


Fig. 24

The high strain levels were reached about 10:00 p.m. and lasted until approximately 7:00 a.m. The minimum strains on the other hand, lasted no more than an hour and occurred in the early afternoon. These readings were recorded during the first week of October in Sacramento and would undoubtedly be different for other climatic conditions. Although air temperature ranged from 55° to 90°F, temperature at the interface between the old and new concrete never varied more than 10°F. The maximum surface temperature of the overlay reached 105°F on the second day and 110°F on the third but ranged between 90°F and 95°F during the remainder of the test.

During periods of maximum strain, the maximum temperature differential between the top and bottom of the overlay was 13°F. It is this differential that causes unbonded concrete slabs to curl at the ends. When the top of the slab is cooler than the bottom, the curl tendency is upwards.

On October 20, another overlay was placed in the same manner as the first except that on one end, the base concrete surface was well sandblasted. Temperatures were somewhat cooler and the slab was shaded by trees by midafternoon. No sign of delamination occurred during the first 14 days. On the 15th day, a tent arrangement was set up over the slab with heat lamps inside. These lamps were turned on during working hours and off at nights and weekends. Depending on weather condition, temperature of the surface could be raised to somewhere between 80° and 100°F. At night with the heat off and the tent open, the temperature would drop to 35° to 45°F.

After 3 days of the heating cycle, delamination was found on the 20th day after placement. The area of debonding at each end was approximately the same, extending about 6 inches along the edges. Although both ends had gradual increases in bond loss over the next 4 days, on day 29, the end which had not been sandblasted was debonded for a distance of 32 in. while debonding on the sandblasted end was only 19 in. The latter end reached an equivalent debonding length on day 44. Heating was sporadic during this period.

A third slab was placed December 8 with half on a sandblasted surface and half on an area that had been roughened with a chipping hammer. After 4 months of natural weathering, no debonding could be detected. On April 7, heating was started and on April 14, after 5 heating periods, delamination occurred on the sandblasted end. Delamination also eventually occurred on the chipped end, although more gradually.

A fourth slab was placed in June with slab preparation similar to that of No. 3. Both ends delaminated within a week with only natural weathering.

Two more overlays were placed in June using similar surface preparation, but utilizing local aggregates with much lower shrinkage characteristics. Delamination of the first slab began on the sandblasted end the day following placement and on the chipped end after two days. Since the temperatures were quite high during this period (90°F+), the next overlay was kept shaded for two days. The sandblasted end began delaminating on the second day, followed by the chipped end a week later.

Three additional overlays of 3 ft x 3 ft dimensions were placed to determine if the size of slab was a factor in delamination. All four corners of each slab delaminated in a period of 2 days to 2 weeks following placement.

Discussion

Every overlay attempt in the post mortem evaluation ended in bond failure. This occurred in spite of special care to provide ideal surface preparation, grout mixing and placing, and concrete handling and curing. The strain gage installations were somewhat disappointing in that they failed to provide definitive answers as to how, when and where delamination occurs. Loss of bond was detected solely from sounding. The gages did indicate that strain development was gradual but subject to a steady increase.

Attempts to model mathematically the conditions which would result in bond failure were not conclusive due primarily to the fact that these analyses are based either on static conditions or predictable changing conditions. In an overlay, the conditions existing within the concrete are constantly changing due to chemical and thermal reactions as well as other factors such as surface drying.

The results of these experiments indicate that the bond failure occurs in shear, due to thermal stresses. Roughening the base pavement by chipping (cold milling in the field) apparently provides shear keys, as well as greater surface areas, to resist bond failure. In our laboratory testing, the chipped areas remained bonded for a longer period of time than the sandblasted ones. In the field, the lane with more aggregate exposed due to loss of surface mortar had less bond failure than the other two lanes. Also, the short sections on each end of the project which were milled off with a cold planer had relatively minor amounts of delamination.

Even with milled surfaces, it appears that bonded overlays using cement grout as a bonding agent will not perform satisfactorily in California. Possibly, the use of a different bonding medium would provide better performance. An experimental overlay placed with an epoxy bond coat has remained bonded for several weeks. It has been subjected to severe thermal shock consisting of heating with heat lamps followed by applications of ice to the surface.

IMPLEMENTATION

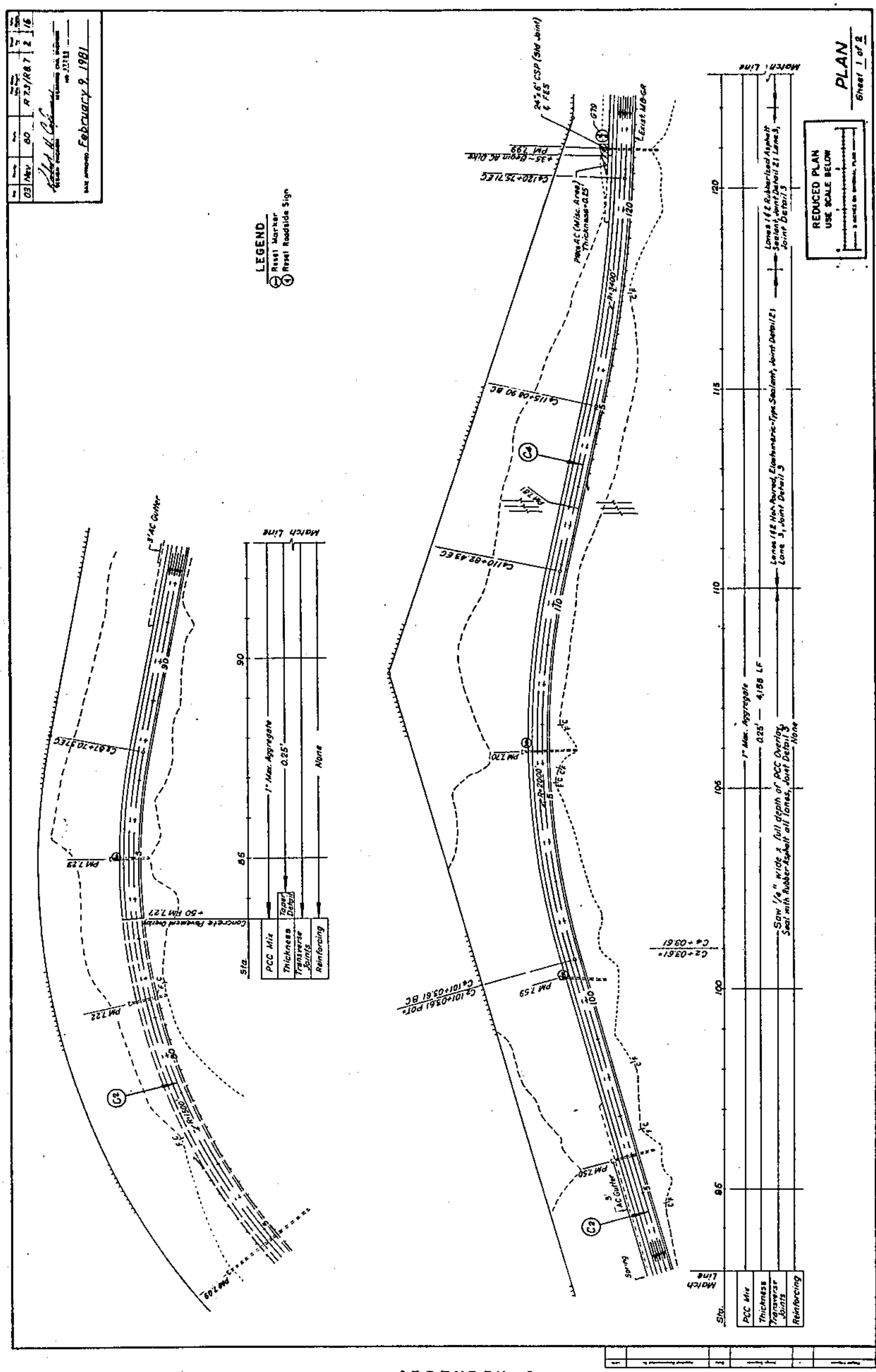
Based on the findings of this study, it is recommended that no additional thin bonded PCC pavement overlays using a cement grout bonding agent be constructed in California unless future laboratory and field studies clearly indicate that the debonding problem has been successfully addressed.

REFERENCES

1. Gillette, R. W., "A 10-Year Report on the Performance of Bonded Concrete Resurfacings," Highway Research Record No. 94, 1965, pp 61-76.

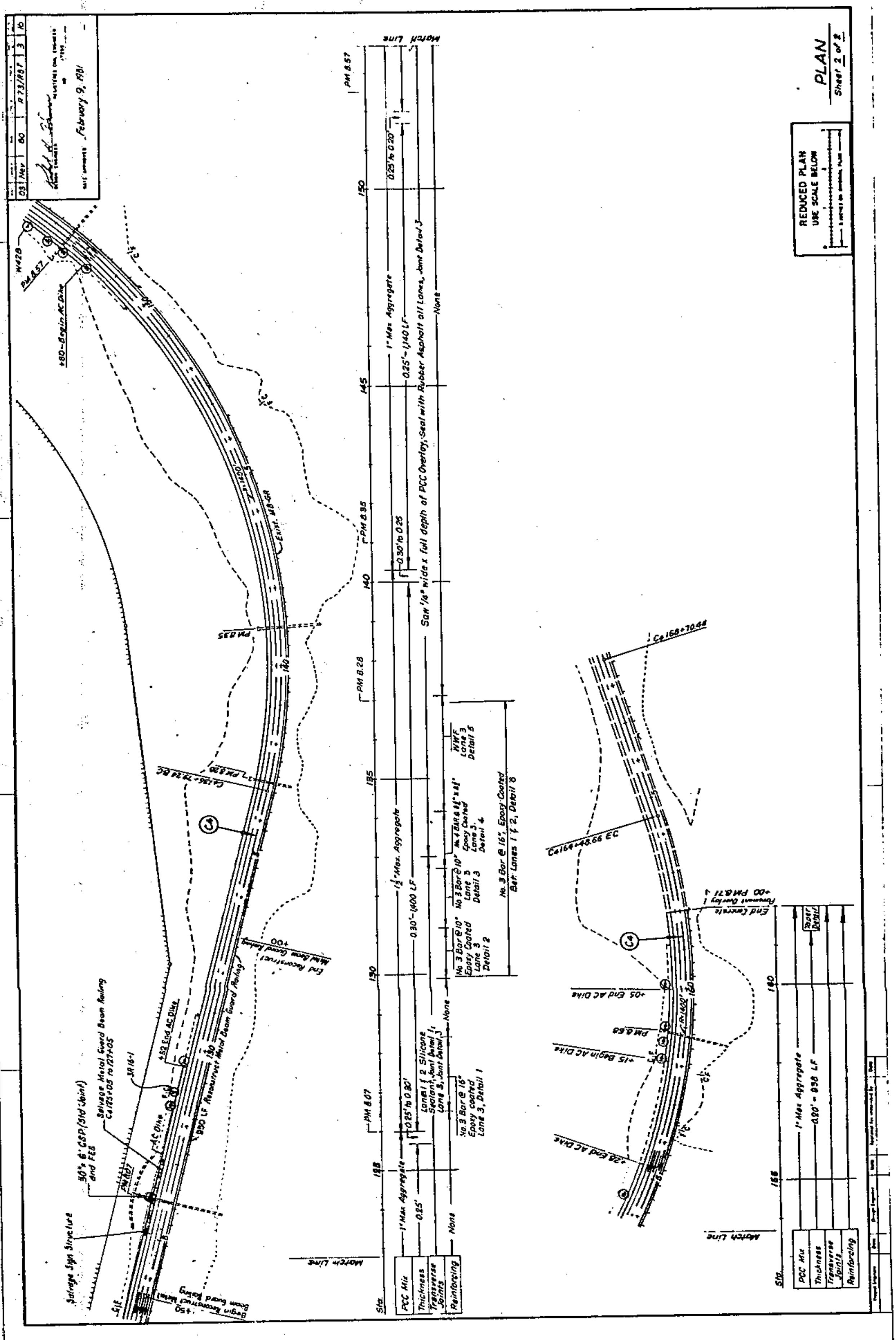
2. Gillette, R. W., "Performance of Bonded Concrete Overlays," Journal of the American Concrete Institute, Vol. 60, No. 1, Jan. 1963, pp. 39-48.

3. Temple, W. H., and Rasoulin, M., "Thin Bonded PCC Resurfacing, Interim Report No. 1," A Louisana Department of Transportation Report, 1982.

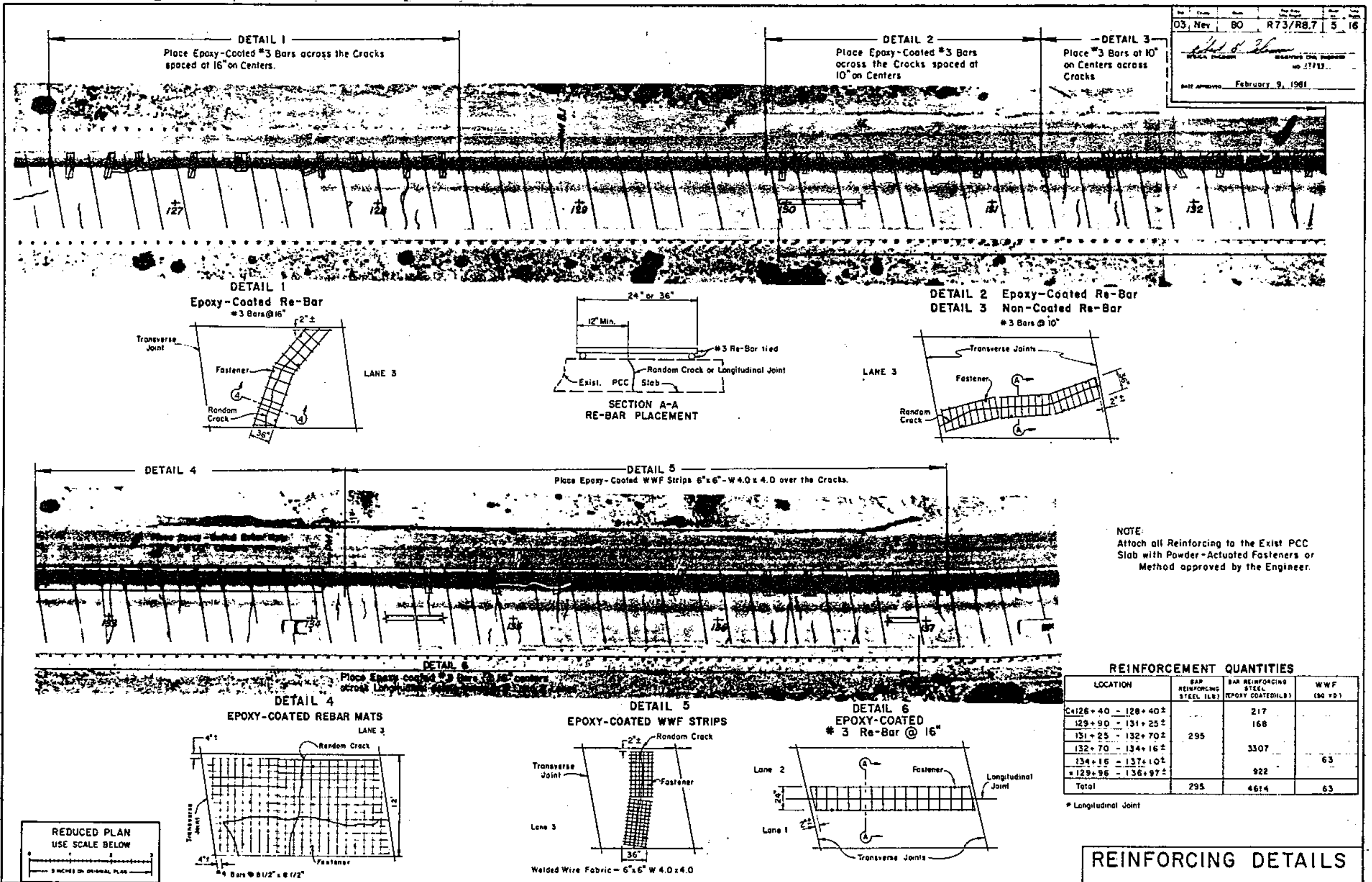


PLAN
Sheet 1 of 2
LEGEND
Reset Marker
Reset Roadside Sign
REDUCED PLAN
USE SCALE BELOW
February 9, 1981
PCC Mix
Thickness
Transverse Joints
Reinforcing
1" Max. Aggregate
0.25'
None
Match Line

APPENDIX A



PLAN
Sheet 2 of 2
REDUCED PLAN
USE SCALE BELOW
February 9, 1981
Match Line
PCC Mix
Thickness
Transverse Joints
Reinforcing
Sta.
1" Max. Aggregate
Saw 1/4" wide x full depth of PCC Overlay; Seal with Rubber Asphalt all Lanes, Joint Detail 3
No. 3 Bar @ 16", Epoxy Coated Bet. Lanes 1 & 2, Detail 6
Salvage Sign Structure
Salvage Metal Guard Beam Railing
850 LF Reconstruct Metal Beam Guard Railing
End Reconstruct Metal Beam Guard Railing
C4 164+48.66 EC
C4 168+70.44



NOTE:
Attach all Reinforcing to the Exist PCC Slab with Powder-Actuated Fasteners or Method approved by the Engineer.

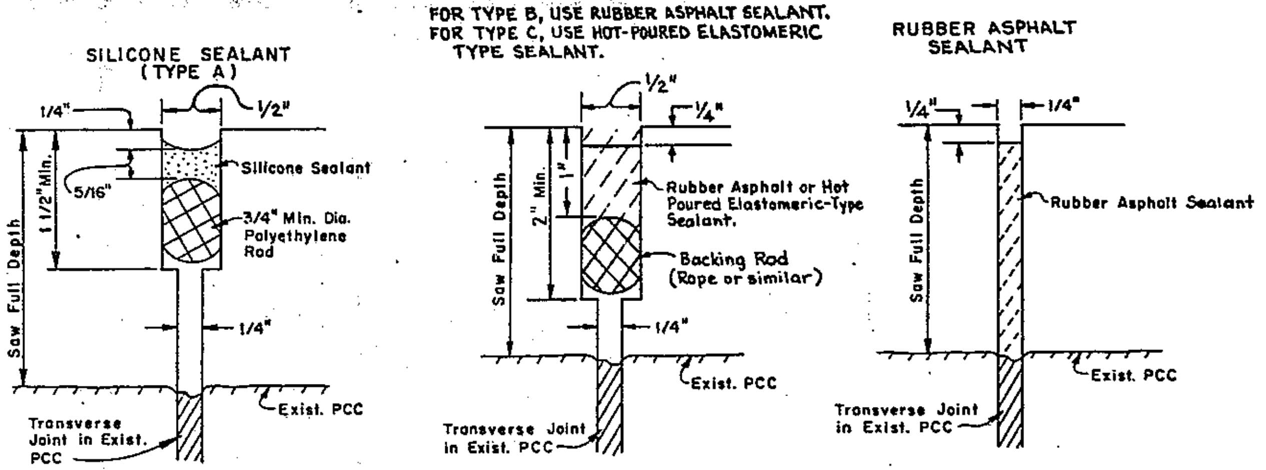
REINFORCEMENT QUANTITIES

LOCATION	BAR REINFORCING STEEL (LB)	BAR REINFORCING STEEL (EPOXY COATED)(LB)	WWF (SQ YD)
C 126+40 - 128+40±		217	
129+90 - 131+25±		168	
131+25 - 132+70±	295		
132+70 - 134+16±		3307	
134+16 - 137+10±			63
* 129+96 - 136+97±		922	
Total	295	4614	63

* Longitudinal Joint

REINFORCING DETAILS

5



DETAIL 1 DETAIL 2

GROOVE & SEAL

DETAIL 3

SEAL

TRANSVERSE JOINTS

No Scale

10-1.16 CONCRETE SURFACE PREPARATION.--Concrete surface preparation shall consists of cleaning the surface of the existing portland cement concrete pavement which is to receive concrete pavement overlay. The entire area to receive concrete pavement overlay shall be cleaned by abrasive blast cleaning. All surface contaminants including, but not limited to rust, oil, paint, joint material, and other foreign material shall be removed from the surface of the existing portland cement concrete pavement.

Water may be used to aid in the abrasive blast cleaning, but the surface of the concrete must be dry immediately prior to placing the grout primer.

Equipment shall be fitted with suitable traps, filters, drip pans or other devices to prevent oil, fuel, grease or other deleterious matter from being deposited on the existing portland cement concrete pavement.

Any area that becomes contaminated shall be recleaned at the Contractor's expense.

Immediately prior to placing grout primer, the surface shall be further cleaned by compressed air blasting to remove loose dust and any other loose material.

Concrete surface preparation will be measured by the square yard. The quantity of concrete surface preparation to be measured for payment will be determined by multiplying the width of the area prepared by the length prepared.

The contract price paid per square yard for concrete surface preparation shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in concrete surface preparation, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Attention is directed to "Grout Primer" of these special provisions.

10-1.17 GROUT PRIMER.--This work shall consist of applying grout primer to the prepared concrete surface just prior to placing concrete pavement overlay.

Grout shall consist of portland cement and water mixed at the approximate rate of 7 gallons of water per 94 pounds of cement.

Portland cement shall be Type II modified. The substitution of pozzolan or the use of Type IP cement will not per permitted.

Portland cement and water shall conform to the requirements of Section 90-2.01, "Portland Cement," and Section 90-2.03, "Water," respectively, of the Standard Specifications.

The consistency of the grout primer shall be such that it can be sprayed onto the existing concrete in a thin, even coating that will not run or puddle. The equipment shall provide uniform coverage across the full width of spray.

The grout shall be agitated prior to and during its use.

Not more than 90 minutes shall elapse between the time water is added to the cement and the time the grout primner is covered with concrete pavement overlay.

After the surface has been prepared and immediately before placing concrete pavement overlay, a thin coating of bonding grout shall be pressure-sprayed onto the dry, pr pared concrete surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect. The rate of progress in applying grout primer shall be limited so that the grout primer does not become dry before it is covered with concrete pavement overlay.

Should the surface of the grout primer indicate any appreciable amount of drying, additional grout primer shall be applied on the area as directed by the Engineer. In areas where the grout primer becomes thoroughly dried, the grout primer shall be removed by abrasive blast cleaning, or other methods as approved by the Engineer. The removal and replacement of grout primer will be at the Contractor's expense.

Grout primer will be measured by the square yard. The quantity of grout primer to be measured for payment will be determined by multiplying the width of the grout primer area by the length of the grout primer area.

The contract price paid per square yard for grout primer shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in furnishing and placing grout primer, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.18 CONCRETE PAVEMENT OVERLAY.--Concrete pavement overlay shall conform to the provisions in Section 40, "Portland Cement Concrete Pavement," of the Standard Specifications and these special provisions.

Portland cement shall be Type II modified. The substitution of pozzolan or the use of Type IP cement will not be permitted.

The concrete for concrete pavement overlay shall contain a minimum of 595 pounds of portland cement per cubic yard.

An air-entraining agent conforming to the requirements in Section 90-4, "Admixtures," of the Standard Specifications shall be added to the concrete at the rate required to result in an air content of 6 1/2 (±1 1/2) percent in the freshly mixed concrete.

A water reducing admixture conforming to ASTM Designation C 494 Type A or D shall be used.

A Certificate of Compliance shall be furnished for the water reducing admixture in accordance with the requirements in Section 6-1.07, "Certificates of Compliance" of the Standard Specifications.

The penetration of the concrete shall not exceed 3/4 inch as determined by California Test 533.

Combined aggregate for concrete pavement overlay, 0.20 or 0.25-foot thick, shall conform to the 1-inch maximum grading, and combined aggregate for concrete pavement overlay 0.30-foot thick shall conform to the 1 1/2-inch maxium grading specified under "Concrete," elsewhere in these special provisions.

The first paragraph of Seciton 40-1.015, "Cement Content," of the Standard Specifications shall not apply.

The ninth paragraph of Section 90-6.02, "Machine Mixing," of the Standard Specificaitons is amended to read:

> Concrete shall be mixed completely in a stationary mixer and the mixed concrete transported to the point of delivery in truck agitators or in nonagitating hauling equipment. (Known as central-mixed concrete.) Only end-dump type trucks will be allowed if concrete is transported in dump trucks.
>
> At least one day prior to paving, a trial batch of concrete shall be mixed using the same operation as will be used during paving. Full compensation for furnishing and mixing the trial batch shall be considered as included in the contract prices paid for the various thicknesses of concrete pavement overlay and no additional compensation will be allowed therefor.
>
> Longitudinal weakened plane joints will not be required.
>
> Lanes 1 and 2 shall be constructed concurrently in the same paving operation.
>
> The longitudinal contact joint between lanes 2 and 3 shall be made to match the longitudinal joint in the existing pavement.

Concrete pavement overlay shall be placed only when the atmospheric and existing pavement temperatures are above 40° F.

The requirements of Section 40-1.135, "Pavement Thickness," shall not apply. Concrete pavement overlay thicknesses shall not be less than the thicknesses shown on the plans.

The second paragraph in Section 40-1.10, "Final Finishing," of the Standard Specifications is amended by adding the following:

> The spring steel tine device shall be operated within 5 inches, but not closer than 3 inches, of pavement edges.
>
> Pavement on tangent alignment and pavement on horizontal curves having a centerline radius of curve 2,000 feet or more shall have a Profile Index of 12 inches per mile or less.

Concrete pavement overlay shall be cured by the curing compound method as specified in Section 90-7, "Curing Concrete," of the Standard Specifications. Curing by the waterproof membrane method will not be allowed. Pigmented curing compound shall be applied at the rate of one gallon per 100 square feet.

When the ambient temperature is above 60° F., the Contractor shall fog the surface of the concrete pavement overlay with a fine spray of water. The surface of the concrete pavement overlay shall be kept moist between the hours of 10:00 a.m. and 4:30 p.m. on the day the concrete pavement ovelay is placed; however, the fogging done after the curing compound has been applied shall not begin until the curing compound has set sufficiently to prevent displacement. Fogging shall be discontinued if ordered by the Engineer.

Transverse weakened plane joints shall be sawn completely through the new concrete pavement overlay directly over all existing transverse joints. Existing joints shall be well marked by the Contractor prior to placing new concrete pavement overlay to assure proper placement of sawn joints.

All transverse weakened plane joints shall be sawn within 12 hours after the concrete pavement overlay has been placed. The exact time will be determined by the Engineer.

Sawn joints shall not be cured with curing compound. Immediately after sawing, the joints shall be filled with rope or a similar material that will prevent excessive loss of moisture from concrete adjacent to the joint. Rope or similar material shall be kept moist for at least 72 hours after placing, or until preparation for the joint seals begins.

Variable thickness concrete pavement overlay will be measured and paid for as concrete pavement overlay of the largest adjacent thickness.

Concrete pavement overlay will be measured and paid for by the square yard in the same manner specified for concrete pavement in Section 40 of the Standard Specifications.

10-1.19 SEAL TRANSVERSE JOINT.--Transverse joints in concrete pavement overlay shall be sealed with rubber-asphalt sealant as shown on the plans and in conformance with these special provisions.

Rubber-asphalt sealant shall conform to the provisions for rubber-asphalt sealant under "Groove and Seal Transverse Joints" of these special provisions.

Immediately prior to applying the sealant, the joints shall be cleaned by blast cleaning or hand methods and then shall be cleaned with high pressure air jets to remove all residue and foreign material. Water jets will not be allowed. Joint surfaces shall be surface dry at the time the rubber-asphalt sealant is applied.

Rubber-asphalt sealant shall be placed in conformance with the manufacturer's recommendations and shall not be placed when the pavement surface temperature is below 50° F.

The finished sealant shall be bonded to the faces of the joint such that there is no separation or opening between the sealant and the faces of the joint and there shall be no cracks, separation or other opening in the sealant.

Any excess sealant on the concrete pavement overlay caused by spills, overfilling the joints, or other reasons shall be cleaned from the surface of the concrete pavement overlay.

Seal transverse joint will be measured by the linear foot.

The contract price paid per linear foot for seal transverse joint shall include full compensation for furnishing all labor, materials, tools, equipment, and incidents and for doing all the work involved in sealing joints as shown on the plans, as specified in the Standard Specifictions and these special provisions, and as directed by the Engineer.

10-1.20 GROOVE AND SEAL TRANSVERSE JOINT.--This work shall consist of cutting grooves coincident with transverse weakened plane joints in the concrete pavement ovelay and sealing the grooved joints with a joint sealant as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

Grooves shall be cut with a power driven saw fitted with diamond blades.

During all construction operations, the Contractor shall protect joints grooved for sealing from intrusion of solid foreign materials into the groove or into the sealant.

Immediately prior to applying the sealant, the joints shall be cleaned by blast cleaning or hand methods and then shall be cleaned with high pressure air jets to remove all residue and foreign material. Water jets will not be allowed. Joint surfaces shall be surface dry at the time the sealant is applied.

Joint seal materials shall be placed in conformance with the manufacturer's recommendations. Joint seal materials shall not be placed when the pavement surface temperature is below 50° F.

The finished joint seal shall be bonded to the faces of the joint groove such that there is no separation or opening between the sealant and the faces of the joint groove, and there shall be no cracks, separation or other opening in the sealant.

Any excess sealant on the concrete pavement overlay caused by spills, overfilling the joints, or other reasons, shall be cleaned from the surface of the concrete pavement overlay.

Joints shall be sealed, as shown on the plans, with low modulus silicone sealant, rubber asphalt sealant or hot poured elastomeric type sealant.

SILICONE SEALANT.--The low modulus silicone sealant shall be furnished in a one-part silicone formulation. The sealant shall be applied with a pressure applicator that forces it into the joint. A tool shall be used behind the applicator in order to force the material against the face of the joint. Polyethylene foam shall be commercial quality with a continuous impervious, glazed top surface, suitable for retaining the sicicone sealant in the joint. The polyethylene foam rod beneath the silicone sealant shall not adhere to the silicone sealant.

The low modulus silicone sealant shall be compatible with concrete. Acetic acid cure sealants shall not be used.

The low modulus silicone sealant shall conform to the following test requirements:

Test Requirements	
Flow	0.3 inches maximum
Extrusion rate (100° to 0°F)	75 - 250 grams/minute
Tack free time @ 77°F. ± 3° and 45 - 55% R.H.	20 - 75 minutes
Specific Gravity	1.01 - 1.515
Durometer hardness, Shore A: cured 7 days @ 77°F. ± 3° and 45% to 55% R.H.	10 - 25 max (at 0°F)
Tensile stress @ 150%, elongation (7 day cure @ 77° F.± 3° and 45 - 50% R.H.)	75 psi maximum
Elongation: (7 day cure @ 77° F. ± 3° and 45 - 55% R.H.)	500% minimum
Peel (adhesion): Unprimed aluminum substrate with aluminum screen (7 day cure @ 77° F. ± 3° and 45 - 55% R.H.)	20 lbs. minimum with at least 75% cohesive failure
Shelf Life	6 months minimum - from date of shipment.
Ozone & U. V. Resistance	No chalking, cracking or bond
Bond to concrete mortar: unprimed concrete briquets air cured 7 days @ 77° F ± 3°	80 psi minimum
Bond to unprimed concrete mortar briquets air cured 7 days then cured in 3% NaOH solution 7 days @ 77° F ± 3°	50 psi minimum

Test Methods

Flow	MIL S 8802
Extrusion rate	MIL S 8802
Tack free time	MIL S 8802
Specific Gravity	ASTM D 792, Method A
Durometer hardness	ASTM D 2240
Tensile Stress	ASTM D 412 (Die C)
Elongation	ASTM D-412 (Die C)
Peel	MIL S 8802
Ozone & UV Resistance	ASTM D-793-75

Bond to concrete mortar: Briquets molded in accordance with AASHTO T 132-74 sawed in half and bonded with a thin section of sealant and tested in accordance with AASHTO T 132-74 briquets dryed to constant weight in oven 110° C ± 5.

A Certificate of Compliance shall be furnished for the silicone sealant in accordance with the requirements in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

RUBBER ASPHALT SEALANT.--The joint sealant shall be a mixture of paving asphalt and ground rubber and shall conform to the following requrirements:

Paving asphalt shall have a maximum penetration at 77° F. of 150, when tested in accordance with Test Method AASHTO T49.

Ground rubber shall be vulcanized or a combination of vulcanized and devulcanized materials. The gradation of the rubber shall be such that 100% will pass a No. 8 sieve.

The asphalt and arubber shall be blended in proportions, by weight, of 75%+2% paving asphalt and 25%+2% ground rubber. Modifiers may be used to facilitate blending.

The rubber-asphalt material shall be furnished premixed in containers with an inside liner of polyethylene. Packaged material shall not exceed 75 pounds in weight. Storage and heating instrucitons and cautions shall be supplied by the vendor with each shipment.

The material shall be capable of being melted and applied to cracks and joints at temperatures below 400° F. When heated, it shall readily penetrate cracks 1/4 inch wide or larger.

At the Contractor's option, joint sealant may be used which conforms to the requirements of ASTM D 3405 and as modified below:

Section 4.2 of ASTM D 3405 is modified to read: Penetration at 77° F. (25° c.), 150 g, 5s, shall not exceed 120.

Section 4.5 of ASTM D 3405 is modified to read: Resilience when tested at 77° F. (25° c.), the recovery shall be a minimum of 50 percent.

A backing rod of rope or similar material shall be placed at the bottom of the groove prior to placing the sealant. The backing rod material shall be compatible with the sealant.

A Certificate of Compliance shall be furnished for the rubber asphalt sealant in accordance with the requirements in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

HOT POURED ELASTOMERIC TYPE SEALANT.--The hot poured elastomeric type sealant shall conform to the specifications of ASTM Designation D 3406.

A backing rod of rope or similar material shall be placed at the bottom of the groove prior to placing the sealant. The backing rod material shall be compatible with the sealant.

A certificate of Compliance shall be furnished for the elastomeric sealant in accordance with the requirements in Section 6-1.07, "Certificates of Compliance" of the Standard Specifications.

MEASUREMENT.--Groove and seal transverse joint will be measured by the linear foot along the completed seal.

PAYMENT.--The contract prices paid per linear foot for groove and seal transverse joints of the types listed in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, (including polethylene foam rods and backing rods), tools, equipment and incidents and for doing all the work involved in grooving and sealing transverse joints, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

CONTRACT PROPOSAL OF LOW BIDDER

ITEM NO.	ITEM CODE	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY	BID	AMOUNT
1	070118	TYPE III BARRICADE	EA	10	150.00	1,500.00
2	073101	TRAFFIC CONTROL SYSTEM	LS	LUMP SUM	50,000.00	50,000.00
3	073134	PORTABLE DELINEATOR	LS	LUMP SUM	10,000.00	10,000.00
4	073143	FLASHING BEACON (PORTABLE)	EA	6	1,000.00	6,000.00
5	073162	TEMPORARY PAVEMENT MARKER (NON-REFLECTIVE)	EA	880	2.00	1,760.00
6	073163	TEMPORARY PAVEMENT MARKER (REFLECTIVE)	EA	465	5.60	2,604.00
7	150711	REMOVE PAINTED TRAFFIC STRIPE	SQFT	5,500	1.40	7,700.00
8	151272	SALVAGE METAL BEAM GUARD RAILING	LF	200	2.00	400.00
9	151286	SALVAGE SIGN STRUCTURE	LS	LUMP SUM	2,500.00	2,500.00
10	151572	RECONSTRUCT METAL BEAM GUARD RAILING	LF	1,000	6.00	6,000.00
11	152301	RESET MARKER	EA	20	23.00	460.00
12	152320	RESET ROADSIDE SIGN	EA	3	120.00	360.00
13	016813	SCARIFY CONCRETE SURFACE	SQYD	500	25.00	12,500.00
14	190101	ROADWAY EXCAVATION	CY	1,400	12.00	16,800.00
15	190185	SHOULDER BACKING	STA	37	70.00	2,590.00
16	198001	IMPORTED BORROW	CY	80	15.00	1,200.00
17	260201	CLASS 2 AGGREGATE BASE	TON	2,200	10.00	22,000.00
18	390301	AGGREGATE (TYPE B ASPHALT CONCRETE)	TON	3,200	33.00	105,600.00
19	391001	PAVING ASPHALT (ASPHALT CONCRETE)	TON	200	33.00	6,600.00
20	394001	PLACE ASPHALT CONCRETE DIKE	LF	1,400	2.00	2,800.00
21	394002	PLACE ASPHALT CONCRETE (MISCELLANEOUS AREA)	SQYD	230	15.00	3,450.00
22	397001	ASPHALTIC EMULSION (PAINT BINDER)	TON	10	200.00	2,000.00
23	016804	CONCRETE SURFACE PREPARATION	SQYD	32,000	1.80	57,600.00
24	016805	GROUT PRIMER	SQYD	32,000	0.60	19,200.00
25	016806	CONCRETE PAVEMENT OVERLAY (0.20" THICK)	SQYD	4,200	10.00	42,000.00
26	016807	CONCRETE PAVEMENT OVERLAY (0.25" THICK)	SQYD	22,000	12.00	264,000.00
27	016808	CONCRETE PAVEMENT OVERLAY (0.30" THICK)	SQYD	6,100	14.00	85,400.00
28	402005	TRANSVERSE WEAKENED PLANE JOINT	LF	19,000	0.90	17,100.00
29	404002	SEAL TRANSVERSE JOINT	LF	15,750	0.62	9,765.00
30	016809	GROOVE AND SEAL TRANSVERSE JOINT, TYPE A	LF	1,800	3.25	5,850.00
31	016810	GROOVE AND SEAL TRANSVERSE JOINT, TYPE B	LF	700	2.00	1,400.00
32	016811	GROOVE AND SEAL TEANSVERSE JOINT, TYPE C	LF	1,365	3.00	4,095.00
33	520101	BAR REINFORCING STEEL	LB	335	1.20	402.00
34	520106	BAR REINFORCING STEEL (EPOXY COATED)	LB	5,000	1.30	6,500.00
35	016812	WELDED WIRE FABRIC (6"X 6",W4.0 X W4.0, EPOXY COATED)	SQYD	70	15.00	1,050.00
36	665022	24" CORRUGATED STEEL PIPE (.064" THICK)	LF	6	60.00	360.00
37	665030	30" CORRUGATED STEEL PIPE (.064" THICK)	LF	6	60.00	360.00
38	705015	24" STEEL FLARED END SECTION	EA	1	400.00	400.00
39	705019	30" STEEL FLARED END SECTION	EA	1	500.00	500.00
40	820107	DELINEATOR (CLASS 1)	EA	60	35.00	2,100.00
					TOTAL	782,906.00

AC OVERLAY

The decision to place asphalt concrete over the new concrete overlay was viewed with apprehension by several engineers familiar with pavement performance in the Sierra. Historically, AC has not performed well in a mountain environment when subjected to chain traffic and freezing and thawing conditions. To provide as tough a surface as possible, the following recommendations were made:

1. Place 0.15 ft leveling course with Type A AC, using 3/4 in. max grading.

2. Place an innerlayer of pavement reinforcing fabric over the leveling course to provide a waterproofing membrane and to aid in preventing or reducing reflective cracking.

3. Place 0.20 ft rubberized asphalt concrete surface course on half the project. On the remainder, place 0.20 ft AC with 1/2% additional asphalt over the optimum recommendation.

The overlay was constructed according to these recommendations during late September and early October, 1981. For the leveling course, 6.2% asphalt was used. For the shoulders and half of the project over the concrete, asphalt content was 6.6%. The rubberized AC had 7.6% binder which consisted of 77% asphalt, 21% rubber and 2% extender oil.

The overlay is being severely tested due to more numerous and heavier than usual winter storms over the past two winters. At last report, although some minor surface pitting is evident, the pavement is considered to be performing satisfactorily.